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Mammographic Feature Enhancement using Singularities of Contourlet Transform

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***Abstract*—Early detection of breast cancer reduces the mortality rate among women. Computer aided enhancement techniques in mammograms assist radiologists in providing a second opinion. In this work, selected modulus maxima of Contourlet Transform and selected zero-crossings of the Contourlet Transform were utilized for enhancing microcalcification features in mammograms while reducing noise. Relevant and strong edge information at various levels was retained based on a parent-child relationship among selected Contourlet coefficients. Experimental results of the proposed techniques based on contourlet transform demonstrate the superiority of the modulus maxima method compared to the zero crossing method in mammographic image enhancement. To validate the methods the mini – MIAS database was employed. Various quality measures considered for performance evaluation are Contrast improvement index, Peak Signal to Noise Ratio, Target to Background Contrast ratio and Tenengrad Criterion.**

***Index Terms*—Mammograms, singularities, Contourlet transform.**

I. Introduction

Breast cancer is one of the leading causes of cancer death among women. According to the statistics in 2011-12, the expected mortality rate due to breast cancer is about 577,190 [1]. According to the Indian Council of Medical Research (ICMR), breast cancer will affect 2.5 lakh women in India by 2015. Detection of microcalcification [2], a possible symptom of breast cancer is a complex task because of the inhomogeneous background and the high noise level in the mammographic images due to emulsion artifacts. Recently, wavelet-based enhancement approaches [3][4][5][6] have been utilized to achieve better performance. To overcome the drawbacks of Wavelet Transform to detect singularities and sharp edges, Contourlet Transform (CT) by Minh Do et al [7], an efficient representation is employed to capture the smooth contours that are the dominant feature in natural images. The proposed algorithm makes use of the multiscale and directionality properties of the CT to enhance clinically important microcalcification features in mammograms while suppressing artifacts such as those due to emulsion discontinuity. Two approaches were employed for the enhancement of the microcalcification features, one employing selected modulus maxima of the contourlet transform coefficients and the other employing selected zero crossings of the same [8]. The performances of both approaches were compared by computing various quality measures. Information regarding singularities of CT is given in Section II while Section III explains the proposed method. Results are discussed in Section IV.

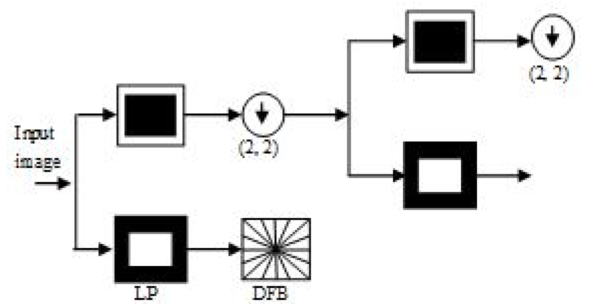

Fig. 1. Block diagram of Contourlet Transform

II. Singularities In CT

Geometric regularity in images, usually image edges are typically located along smooth contours [9]. Thus, image singularities are localized in both location and direction. A fast decaying function can be utilized for singularity detection [10]. Contourlet functions can “capture” edge irregularities of the image. The filterbank for implementing the Contourlet Transform is as shown in figure 1. The Laplacian Pyramid (LP) filter bank and Directional Filter Bank (DFB) implements multiscale and multidirectional decomposition respectively. Impulse response of a bandpass arm at one level of contourlet decomposition constitutes the combined impulse responses of filters in LP as well as DFB. The combined impulse response can be obtained by considering an input image with a single white pixel centered in a black background as shown in figure 2. The orientation characteristics of combined impulse response is decided by the directional filters used and the specified number of directional decomposition levels. The contourlet coefficients have infinite directional vanishing moment, if the filters in the contourlet construction are sinc-type filters with ideal response. Vanishing moments have significant effects for efficient approximation.

Even though one dimensional wavelets provide optimal approximation of piecewise smooth signals, an optimal nonlinear approximation rate for piecewise C^2 images is possible through CT due to the presence of vanishing moments [11]. The nonlinear approximation error decays for Contourlet transform as $O(\log_2 M)^3 M^{-2}$ compared to $O(M^{-1})$ for wavelets where M represents number of most significant coefficients [8]. Sharp variation points in an image can be determined by using its first or second order derivatives.S. Mallat and S. Zhong[12] calculated the local maxima of discrete wavelet transform at each scale and formed a multiscale edge

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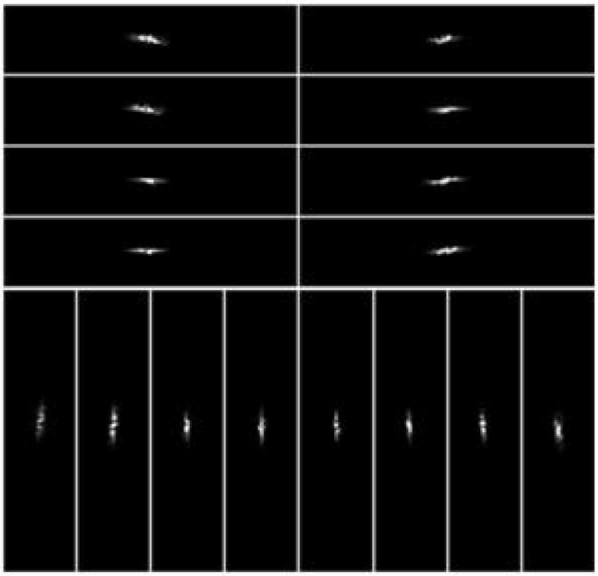
Fig. 2. Combined impulse response after 4 level directional decomposition with 'pkva' filter for pyramidal decomposition and '9/7' for directional decomposition.

representation of an image which characterizes the shape of irregular structures while S.Mallat[13] considered zero-crossings. The extremas of the first derivative are in accord with the zero-crossings of the second derivative and to the singularities. Even though local extrema as well as zero crossings are similar procedures for edge detection, local extrema method has got important advantages.A local modulus maxima indicates sharp variation points while local modulus minima indicates slow variations. These two types of extremas are not possible in the case of zero-crossings. Fluctuation in discontinuities cannot be differentiated in zero crossings even though it provides the information about position. The singularities of directional coefficients of CT at various levels were utilized in the proposed method. Parent-child relationship among corresponding coefficients as shown in figure 3 is considered to reduce the artifacts [14].

III. Proposed Method

Detail coefficients obtained from pyramidal decomposition having large absolute values correspond to sharp intensity changes indicating edges. Microcalcifications can be considered as objects defined by discontinuities or edges. Calcifications represent high spatial frequencies in the image. Thus, one approach to the calcification detection task is to localize the high spatial frequencies of the image. The proposed method discusses a method for enhancing microcalcification by suppressing various artifacts such as due to Poisson noise. The algorithm makes use of the multiscale and directionality properties of the Contourlet Transform at various levels. The high directional perceptiveness and anisotropy property of needle-shaped elements of Contourlet Transform are very proficient in representing edges. Singularities at different scales identified by the presence of modulus maxima of Contourlet coefficients can be used to locate the sharp variation points of

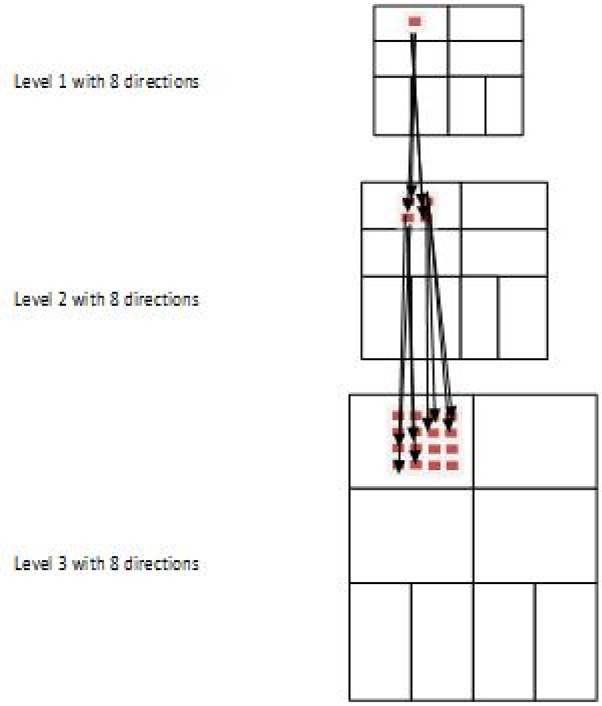

Fig. 3. parent-child relationship with same number of directional decomposition

microcalcification in mammographic image. The modulus maxima thus identified were pruned by utilizing the directional characteristics of Contourlet Transform satisfying the parent-child relationship [15], to remove Poisson noise artifacts. The approach was compared against the one where zero crossings of the Contourlet Transform were employed instead of modulus maxima .It was observed that the method based on modulus maxima of the contourlet coefficients outperformed that based on the zero crossings of contourlet coefficients.

The algorithm employed is summarized below,

1) Compute Contourlet coefficients of image using the Laplacian Pyramid and Directional filter bank decomposition of Contourlet Transform

2) Discontinuities in each subband at different levels are determined using corresponding modulus maxima/zero crossings

3) Coefficients holding parent–child relationships are retained and others are pruned out.

4) The directional subband coefficients corresponding to the selected modulus maxima and also on either side of them are boosted by a factor of four. In the case where zero crossings are employed, directional subband coefficients on either side of selected zero crossings are boosted by a factor of four.

5) This is added back to the directional subbands obtained from step 1.

6) Apply Pyramidal directional filter bank reconstruction by suppressing approximation coefficients obtained from step 1.

7) Threshold (8* standard deviation) this image to get segmented microcalcifications.

8) Perform Pyramidal directional filter bank reconstruction

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including the approximation image to get the mammogram image enhanced for microcalcification features.

IV. Results And Discussion

The database used for the proposed work comes from the mini-MIAS mammographic database [16]. The proposed algorithms were tested on the 25 images with microcalcifications and the performance measures were computed. In order to evaluate the enhancement results of the proposed methods, the contrast improvement index (CII), the peak signal-to noise ratio (PSNR), Target to Background Contrast (TBC), and Tenengrad criterion[9][17][18] were employed.

The low pass filters employed at the LP stage are derived from the PKVA filters [19] and the fan filters at the DFB stage are derived from the BIOR 9, 7 filters [20]. Three levels of the Laplacian Pyramid with four levels of the Directional Filter Bank (i.e., 16 directional subbands) at each level of the LP decomposition were employed for the contourlet decomposition of the mammogram images. The PKVA filter is designed by Phoong, Kim, Vaidyanathan, and Ansari with support size of (23, 23) and (45, 45) .The filters were selected since the combined impulse response of the band pass arm of the contourlet filter bank exhibited the necessary property of being the double derivative of a smoothed function. The directional subband coefficients corresponding to the selected modulus maxima and also on either side of them directional subband coefficients on either side of selected zero crossings were boosted by a factor of four. Figure 4 shows the reconstructed images of Mdb249 and Mdb211 obtained after the inverse Contourlet Transform using zero-crossings and modulus maxima techniques. Mdb249 is a mammogram with dense glandular background tissue and Mdb211 is a difficult to detect mammographic image. It contains well-defined malignant microcalcifications.

The value of TBc, Contrast and CII of the proposed method indicates that the enhanced image with modulus maxima is superior with a larger contrast, to that with the Zero-Crossing method. The improvement in sharpness indicates that there is contrast enhancement which is verified by analyzing the Tenengrad criteria values. The improvement in PSNR and ASNR values shows the noise reduction in enhanced image. The Modulus Maxima method has got 17.9% improvement in visual appearance, 11.3% increase in contrast as well as Contrast improvement index, 21.7% improvement in noise reduction and 0.26% improvement in sharpness compared to that of zero crossings method.

Conclusions

In this paper, selected modulus-maxima and zero crossings of the Contourlet coefficients were employed for mammographic image enhancement. Directional subband coefficients corresponding to the selected modulus maxima and also on either side of them in the modulus-maxima tree, in the direction of the corresponding directional filter, were boosted, while the modulus-maxima that exist at only the finest scales were suppressed. For the zero crossing strategy, the coefficients on either side of the zero crossings were employed instead. Relevant edge features including microcalcification structures were enhanced while image artifacts that exist at only the finest scales were suppressed. Quality measures including Contrast, CII, PSNR, ASNR, TBc and TEN were calculated to determine the efficiency of the proposed methods. The results were verified by checking the information provided by the radiologists in mini-MIAS database and were found promising.

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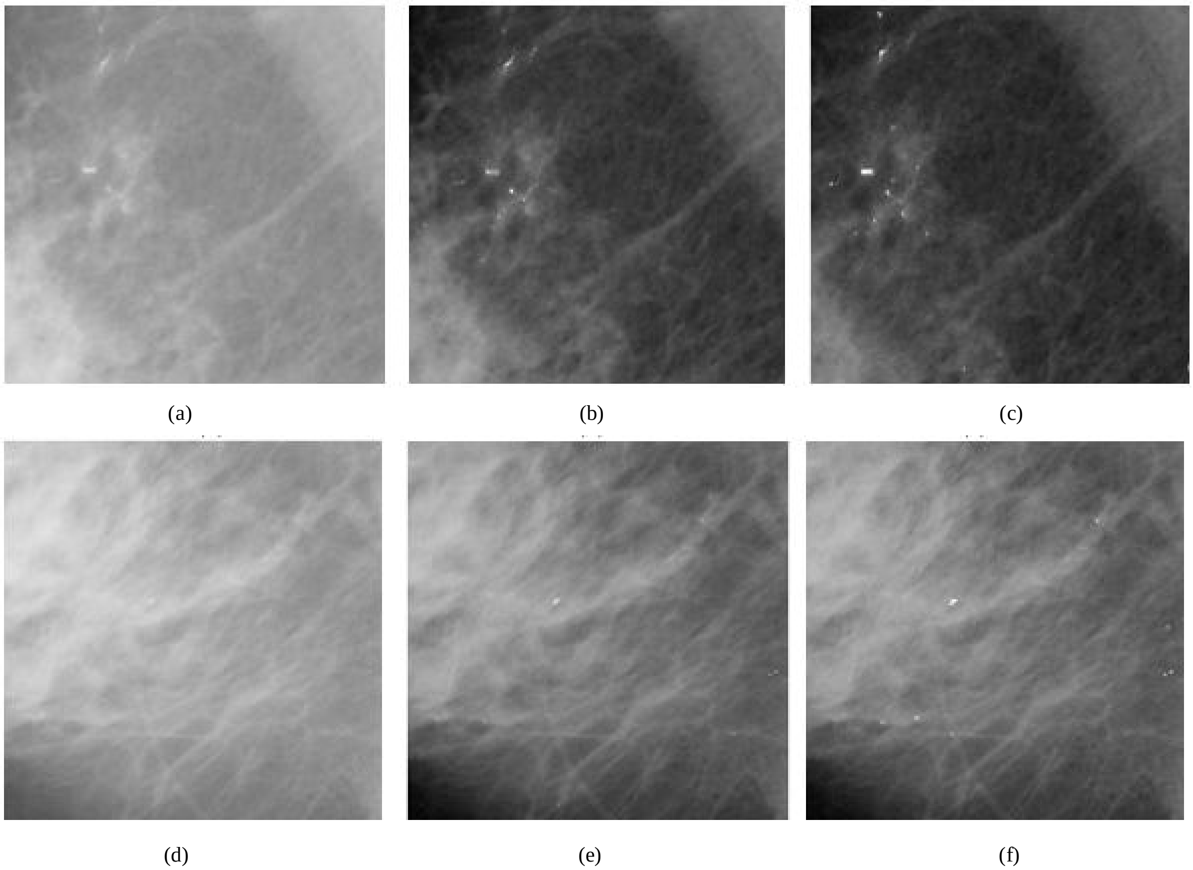

Fig. 4. The enhanced results of microcalcifications in mdb249 and mdb211 respectively (a) (d)original, (b) ,(e)enhanced by the contourlet approach using zero-crossings (c)(f) enhanced by the contourlet approach using modulus-maxima.

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